Just regime scour

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SCOUR AND BANK MIGRATION

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NORTHWEST ALASKAN PIPELINE COMPANY

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1.1 INTRODUCTION

Water flowing in natural or artificial channels has the ability to scour sand, gravel, and even large boulders from the bed or banks and carry them downstream. Work to set the water in motion is provided by the potential energy gradient from the relief of the watershed. The river channel serves as a location for energy dissipation as flow from the entire watershed is collected there. In fixed bed hydraulics, energy is dissipated by friction, and expansion and contraction losses. In natural streams, energy is dissipated in transport of the water, transport of the suspended sediment, and through transport of the bed material. For steady state discharge conditions, a natural balance is maintained between the water sediment mixture in the stream, and the material forming the boundary of the stream channel.

For the transport of sediment to increase while the water discharge remains constant, either the effective grain size in the sediment load must decrease (mainly achieved through change in sediment load itself, or through change in temperature of water, which changes viscosity), or the transported load is increased through bank scour. A change in the energy gradient will also induce a corresponding increase in the sediment loads, as will a change in the bed resistance (i.e. from a dune configuration to a plane bed). This latter change may be particularly evident in sand bed channels. As the discharge within a stream increases, the available energy increases, with a consequent increase in the total sediment load.

This report considers scour problems related to pipeline river crossings, either in the buried or elevated mode. The buried mode considerations primarily involve the potential for pipe exposure or movement, while the elevated mode conditions should consider the possibility of foundation undermining, or changes in stream alignment due to bank migration or incision.

Two types of scour must be considered in the design. The first is the general scour associated with parallel flow in a relatively straight channel and the second is the local scour caused by abrupt changes in curvature of flow lines and secondary flow. General scour occurs during the passage of a flood event irrespective of whether structures are present or not. As such, total scour estimation is computed as the sum of general and local scour if structures are present at a particular site. Long term elevation changes in the bed of a stream, resulting from the passage of numerous flow events, is normally referred to as degradation or aggradation.

2.0 REVIEW OF SCOUR ESTIMATION METHODS

2.1 GENERAL SCOUR

Many difficulties exist in the analytical definition of the processes delineating sediment transport, and consequent scour depth estimation. These difficulties arise from the large number of interrelated variables affecting the behavior of stream channels. Because of this complexity, no single method for estimating scour can be considered totally definitive. An estimate should be made from an evaluation of the independent methods which are outlined in the following sections. Not all methods will apply to every stream, and the method most applicable for the stream should be more heavily weighed in the estimation of scour.

2.1.1 Evidence of Historic Scour Limits

The most reliable estimates of scour may be obtained from comparison of cross section profiles collected during high flow events. Unfortunately, very little data of this nature exist, and flood stage cross section profiles are usually only available if discharge measurements have been made at the time of the event.

Evidence of scour limits may also be found with the occurence of organic material found in borehole logs, alteration of minerals in the alluvium, and the occurence of armour layers in borehole logs and test pits. Data of this nature should be investigated in estimation of scour at stream crossings.

2.1.2 Regime Method

Channels constructed in alluvium tend to adjust their boundaries until a stable relation involving depth, bed material, and velocity of flow is obtained. Canals that achieve this state are said to be in regime. Engineers attempting to apply this relation to natural streams found that the major difference between a natural stream and an irrigation canal is that, whereas in natural streams flows are highly variable, irrigation canals tend to operate at a fixed discharge. Application of the regime method necessitates the use of empirical judgement on behalf of the engineer, and, in general, is only applicable to flows with low Froude numbers, usually within the ripple to dune flow regime.

2.1.3 Mathematical Modelling

During the last decade, computer oriented water/sediment routing models have been developed to assist in the delineation of the interaction between suspended sediment, bed material movement, water velocity, and flow depth. These models, which consider a stream reach in preference to a single location, and may be operated to route complete hydrographs, generally require far more extensive data and computer time than alternate methods. These models are most applicable to the study of long term aggradation or degradation in streams, and in the estimation of bed elevation changes resulting from encroachments within floodplains or stream bed modification.

In conjunction with the large data requirements for execution of these models, empirical flow data and aggradation or degradation measurements are required to calibrate and verify the model prior to its use in estimating future bed elevation changes.

2.2 Local Scour

Local scour occurs in non-uniform flow regions where the water-sediment mixture is accelerated or decelerated. The major causes of local scour are the fluctuations of forces such as pressure, lift, and shear.

Local scour is a function of many factors, such as the channel slope, channel cross section, bed material, transported sediments, flow direction and duration, ice, logs, man-made hydraulic structures, etc. The number and complexity of these factors have led to the development of experimental and theoretical approximations.

Some of the methods described in Section 2.1 can also be used to predict scour in a limited contraction.

again - it sounds like they need suspended sediment data.

3.0 SCOUR DEPTH ESTIMATION METHODOLOGY

This section describes the procedures used for estimation of scour depth at a particular location in a stream. In addition, various approaches to scour have been described for special cases.

3.1 Flow Chart

From the flow chart given in Figure 1, the first step is to define the stream as an alluvial fan, braided, split channel, meandering or sinuous stream. The second step is to classify the stream as a major or minor stream. A major stream has a pipeline design flood greater than or equal to 10,000 cfs, while a minor stream has a pipeline design flood less than 10,000 cfs and greater than or equal to 1,000 cfs. The next step is to evaluate historic scour limits from surveyed cross section data and borehole logs. The next step is to determine the hydraulic parameters of the cross section for which scour is to be computed. General scour is then computed in the main channel and on the floodplain, if applicable. If structures are present, local scour is computed and added to general scour to determine the total scour at a location. The total scour is then compared with historic scour limits, if available, and the "Z" factors are modified if necessary.

3.2 Special Cases

3.2.1 Alluvial Fans

Scour and bank migration on alluvial fans may occur under two independent modes. Within the fan itself there is a possibility that channel switching may occur, as most alluvial fan streams are perched. However, general or local scour is usually not significant as alluvial fans are in an aggrading mode.

If the downstream channel is extremely unstable, there is a possibility that lateral bank movement may shift into the alluvial fan, changing the bed slope of the fan stream, and consequently inducing extensive headcutting. The main channel will be evaluated morphologically to ascertain the probability of this occurring, and if necessary, remedial measures recommended to prevent headcutting. If no alternative crossing locations are available on the fan, the worst case scenario of head-cutting, and the resulting stabilized new stream bed elevation under the condition of most lateral bank migration, shall be used as the design criteria for scour.

A how many streams like this?

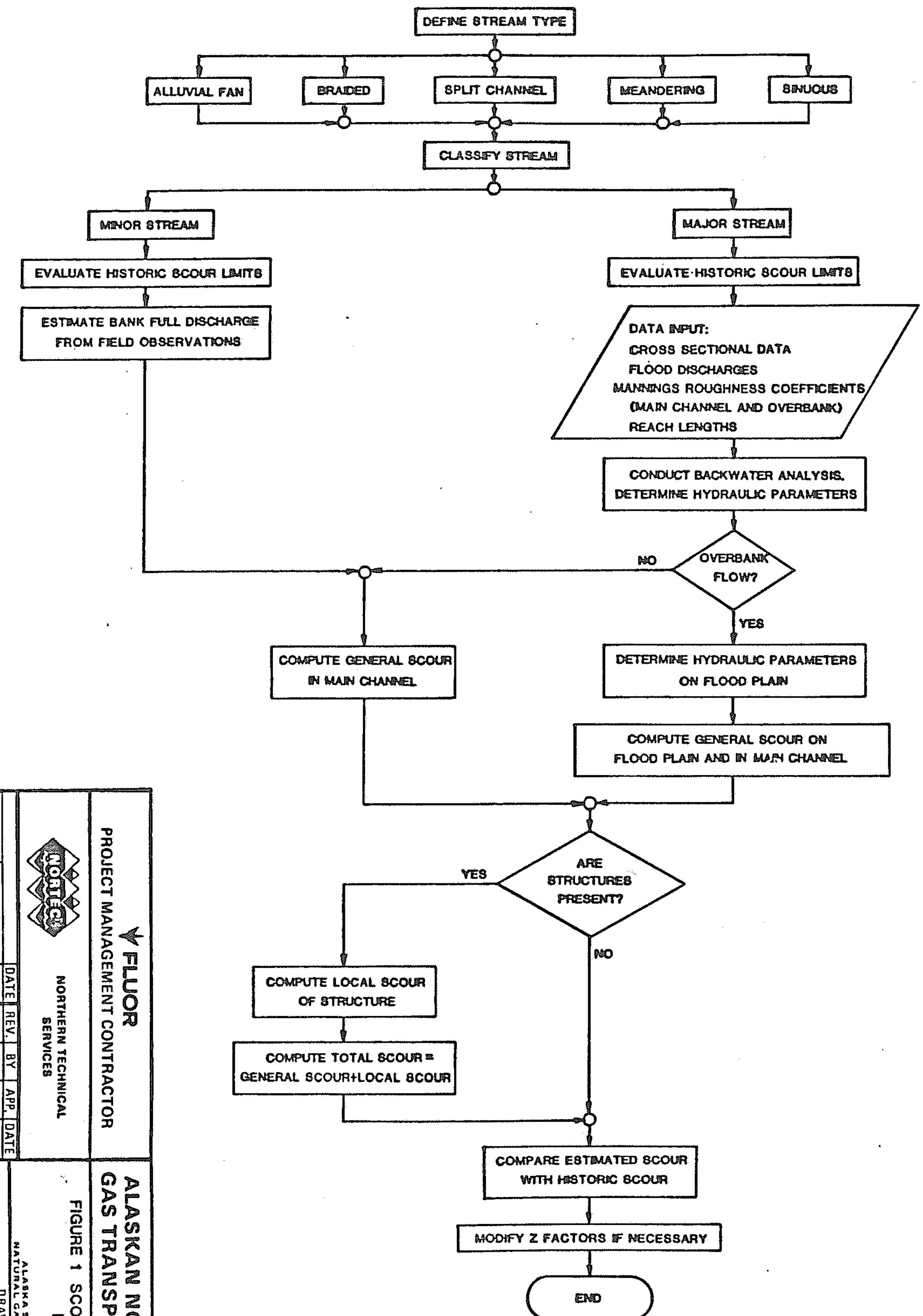

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FIGURE 1 SCOUR DEPTH ESTIMATION FLOW CHART

ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

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3.2.2 Multiple Channels

If multiple channels exist under the design flood conditions, the maximum stage recorded shall be used for the computation of scour depth. At locations where the pipeline will be placed adjacent to a channel other then the main channel, scour computations will be conducted at this channel also.

3.2.3 Icings and Aufeis

The effect of ice upon the stream, especially the effects upon bank erosion during break-up events, can be the most influential factor in significant stream morphological changes. All general and local scour estimates will be made in conjunction with observed aufeis and icing conditions at the site. Ice induced bank erosion shall also be assessed during the bank migration evaluation.

3.2.4. Floodplain Scour

If, following the backwater analysis, overbank flow occurs, the overbank flow depths will be evaluated, in conjunction with the associated velocities to determine if detrimental erosion is likely to occur on the floodplain.

3.2.5 Unclassified Streams

For small, unclassified streams, scour depth estimation shall be made from evaluation of historic data and an estimation of the bank full discharge from field observation. Estimated scour shall then be computed at the maximum depth section, using estimated bed material sizes from field observation.

If structures are present at the site, the possible effect of the crossing upon the structure and vice versa shall be evaluated qualitatively and from any historic data available at the site.

4.0 SCOUR ESTIMATION FORMULATION

4.1 GENERAL SCOUR

4.1.1 Regime Theory

The regime depth can be computed by the Blench equation (Reference 3). The equation is given by

$$d_r = \sqrt[3]{(q^2/F_b)} \qquad (1)$$

where d_r = regime depth, in feet,

q = unit discharge in cfs/ft,

F_b = bed factor.

For subcritical flow Blench defined $F_b = F_{bo}\ (1 + 0.12\ C)$ (2)

where C = bed load charge

and F_{bo} = zero bed factor defined for sand and gravel bed streams in the following two equations, respectively.

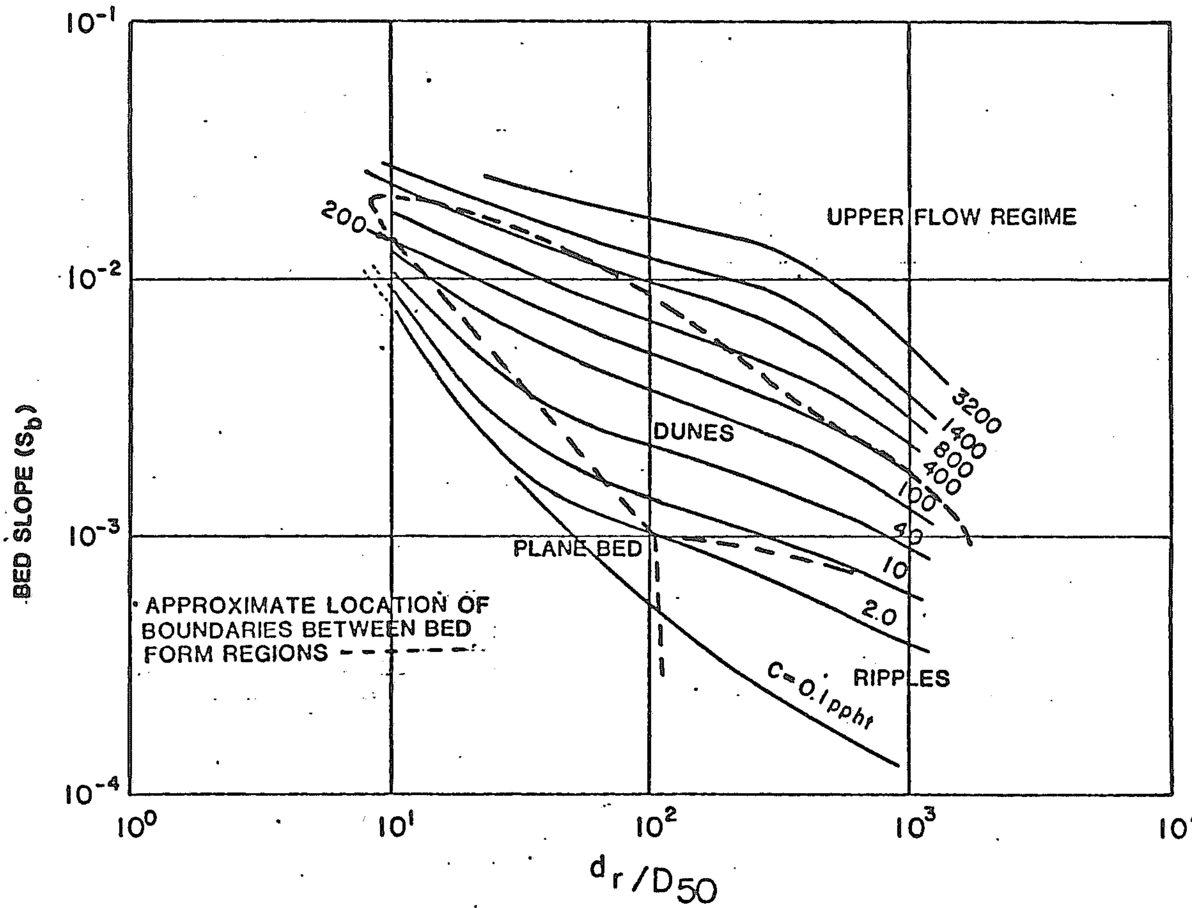
$$F_{bo} = 1.9\ (D_{50})^{0.5} \qquad (3)$$

$$F_{bo} = 7.3\ (D_{50})^{0.25} \qquad (4)$$

where D_{50} = representing diameter of bed material, in feet.

The bed load charge may be determined from Figure 2 adopted from Reference 1.

A scour depth is then determined by applying a factor to the computed regime depth. The multiplication "Z" factors or factors are related to the erodibility of the bank and are based on both field and model results. Table 1 lists recommended "Z" factor ranges for various stream locations for two flow conditions.



SLOPE – d_r/D_{50} RELATION FOR FLOW IN ALLUVIAL CHANNELS AT VARIOUS VALUES OF BED-LOAD CHARGE, C (AFTER COOPER, PETERSON BLENCH REFERENCE)

FLUOR PROJECT MANAGEMENT CONTRACTOR	ALASKAN NORTHWEST NATURAL GAS TRANSPORATION COMPANY
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	ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

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TABLE 1

RECOMMENDED "Z" FACTORS FOR REGIME METHOD APPLICATION

Location on Stream	Flow Condition: Pipeline Design Flood Stage	Flow Condition: Bankfull Stage
Forced, Rigid Bends	1.40 - 2.50	1.40 - 4.00
Free, Eroding Bends	1.40 - 1.75	1.40 - 2.50
Confluence	1.50 - 2.00	2.00 - 3.00
Tips of Spurs	2.00 - 2.75	2.50 - 4.00

Where appropriate field measurements are not available, scour depths may also be estimated by using Lacey's empirical regime formula (References 4 and 5).

$$Y = 0.47 \frac{Q^{1/3}}{f}, \qquad (5)$$

where Y = the regime depth as described,
Q = the design flood,
and f = Lacey's silt factor.

Lacey's silt factor is given in Table 2 (Reference 4).

TABLE 2

VALUES OF LACEYS SILT FACTOR "f"

Median grain size, mm	f - Value
0.08	0.50
0.16	0.70
0.23	0.85
0.32	1.00
0.50	1.25
0.72	1.50
1.00	1.75
1.30	2.00

Equation (5) provides only the regime depth. To estimate scour depth, a multiplying factor should be applied as in Blench's method. The formula (equation 5) is only applicable to sand bed material, and it may tend to overestimate scour depth in coarser materials.

Very little literature is available summarizing appropriate "Z" factor values for different stream types, bed material types, and actual locations within the stream. As such, estimation of the Z factors requires extensive in-field application experience on behalf of the engineer using the regime methodology, and, as mentioned previously scour depth estimations from the regime equations shall be compared to any historical data available, and to the computed scour resulting from the water/sediment routing model applied to major streams. Also, normal depth or HEC-2 will be used for determination of flood elevations and other hydraulic parameters at the particular cross section. Note should be made that both of these methods assume rigid boundary conditions and HEC-2 may not be applicable at flow regimes approaching the critical range, in which case normal depth computations shall be used.

4.1.2 Mathematical Modeling

The following section outlines the basic philosophy behind a majority of the currently available water/sediment routing programs. Numerous models have been evaluated with regard to their applicability to Alaskan streams and their ease of use, and a separate report on the adopted model is forthcoming.

The basis for simulating the moveable bed has two major features. One is the numerical solution of the sediment continuity equation (the Exner equation), and the other is the computation of bed material transport using a sediment transport formula suitable for each stream crossing. The continuity equation for sediment material is given by:

$$\frac{\partial G}{\partial X} + B_o \frac{\partial Y}{\partial T} = 0 \qquad (6)$$

where G = Volume sediment transport rate, in cfs,
T = Time, in seconds,
Y = Depth of movable bed, in feet,
X = Distance along the channel, in feet,
B_o = Width of movable bed, in feet.

The selection of existing sediment transport formulae is made in relation to the gradation of material in the stream bed and the hydraulic characteristics of the stream channels. Available sediment transport methodology has been derived primarily from consideration of the physical processes, laboratory data, and some in-field data. As such, a universal sediment transport equation, to cover the broad range of scour computation from gravel bed to sand-bed alluvial streams, is not possible at present. For gravel beds, the Meyer-Peter Mueller method is recommended. For sand-bed streams, the Einstein, Modified Einstein, Colby, or Toffaletti method will be integrated into the sediment routing model for delineated discharges.

4.2 LOCAL SCOUR

4.2.1 Scour at Bridge Piers

Local scour at bridge piers is caused by the development of vortex systems at the pier. At the upstream nose of the pier, a vortex with a horizontal axis is developed and wraps around the base of the pier. Downstream of the pier, a wake - vortex system with a vertical axis is developed as a result of blockage of flow by the pier. These vortex systems account for the development of scour holes at the base of bridge piers on the upstream and downstream sides of the pier.

The strength of these vortex systems is largely a function of the pier shape at the upstream and downstream faces. A streamlined pier will reduce the strength of these vortices and thereby reduce the amount of local scour that occurs at the pier.

Results of field work on local scour at bridge piers in Alaska have yielded generalized formulae for the estimation of scour depth. These generalized formulae relate local scour depth to the width of the pier for ranges of bed material sizes. In Reference 6, the U.S. Geological Survey recommends the following equations for determination of design scour depths at cylindrical, round or pointed nose piers aligned parallel to flow.

$$d_s = 3b^{.8}$$ for bed material of medium silts to fine sands (7)

$$d_s = 2b^{.8}$$ for bed material of medium sands to fine gravels (8)

$$d_s = 1.2b^{.8}$$ for bed material of medium gravel to coarser (9)

where

b = width of pier in feet

and

d_s = maximum equilibrium scour depth for given pier and sediment size, measured from the mean or ambient bed elevation around the hole

For pier shapes other than cylindrical, round or pointed noses with piers aligned paralled to flow, the Larras equation in Reference 6 is recommended for the determination of local scour depth at piers.

The Larras equation is as follows:

$$d_s = 1.42kb^{.75} \quad (10)$$

where k = pier shape factor for various pier nose forms

and b and d_s are as defined previously.

Values of the Shape factor "k" can be found in the following table from Reference 2.

TABLE 3

RECOMMENDED "k" FACTORS FOR PIER NOSE SHAPES

SHAPE	LENGTH: WIDTH RATIO	k
Rectangular	N/A	1.0
Semicircular	N/A	.9
Elliptical	2:1	.8
Elliptical	3:1	.75
Lenticular	2:1	.8
Lenticular	3:1	.7

For piers skewed to the flow, the depth of scour is determined by.

$$d_{sk} = (\text{Multiplying factor}) \times (d_s) \quad (11)$$

where d_{sk} = depth of scour for skewed piers

and d_s is as defined previously.

The multiplying factor can be found in Table 4 from Reference 2.

TABLE 4

MULTIPLYING FACTORS FOR DEPTH OF SCOUR

AT SKEWED PIERS

Horizontal Angle of Attack	Length to Width Ratio of Pier in Flow			
	4	8	12	16
0	1.0	1.0	1.0	1.0
15	1.5	2.0	2.5	3.0
30	2.0	2.5	3.5	4.5
45	2.5	3.5	4.5	5.0
60	2.5	3.5	4.5	6.0

These procedures will be used to determine the local scour around bridge piers or piles at pipeline river crossings.

4.2.2 Scour at Spur Dikes and Guide Banks

Local scour for the embankments, such as spur dikes, guide banks, abutments, etc; is also caused by the action of vortex systems developed by the embankment blockage to flow. The vortex of fluid generated by the pileup of water on the upstream edge, and subsequent acceleration of flow around the nose of the embankment are the major mechanisms for local scour around embankments.

The study of local scour around embankments is dominated by laboratory experimentation. Results of laboratory work have yielded generalized formulae for the estimation of local scour depth at embankments. Again, these generalized equations relate local scour depth to the upstream depth of flow, the upstream Froude Number, and the pier shape. For sand bed streams, the scour depth at an embankment can be estimated by the equation

$$\frac{ds}{d_1} = 1.1\left(\frac{a}{d_1}\right)^{0.40}\left(Fr_1\right)^{0.33} \qquad (12)$$

where ds is the equilibrium depth of scour measured from the mean bed level to the bottom of the scour hole,
d_1 is the upstream depth of flow,
Fr_1 is the upstream Froude Number,
and a is the embankment length measured normal to flow

Likewise, if the embankment has vertical walls on the upstream and downstream side then the equation is

$$\frac{ds}{d_1} = 2.15\left(\frac{a}{d_1}\right)^{0.40}\left(Fr_1\right)^{0.33} \tag{13}$$

This method will be used to predict the local scour at embankments such as spur dikes, guide banks, etc; in the bank protection and river training works.

Further discussion of local scour phenomena and its application to bridge piers, spur dikes and guide banks can be found in References 2 and 7.

5.0 BASIC DATA REQUIREMENTS AND PREPARATION

5.1 GENERAL SCOUR

5.1.1 Historic Scour Limit Data

Basic data requirements for this evaluation method requires comparative cross sections (or depth soundings) recorded during both low flow and high flow conditions. Borehole logs and exploratory geologic data will also assist in determining past bed elevations and consequential scour depth.

5.1.2 Regime Method Data

Primary data requirements include the general hydraulic cross section parameters, including velocities and maximum depths. The design discharge and peak unit width discharges are also required together with size gradations of the bed material. The selection of appropriate "Z" factors requires considerable experience in river engineering hydraulics and design.

5.1.3 Mathematical Model Data

The following is a basic summary of data requirements for scour estimation using mathematical models. A complete description of data collection techniques and preparation for the model may be found in the forthcoming report specifically addressing model use.

Basic data for water/sediment routing models include

1. Initial channel geometry, including a detailed description of natural levees along the channel.

2. Gradation of suspended load and streambed material.

3. Water discharge hydrograph.

4. Water temperature.

5. Suspended sediment data.

5.1.4. Bed Material Data Collection Methodology

The regime method and mathematical model both require as input the d_{50} and d_{90} of the bed material. The d_{50} is defined as the diameter of sediment particles for which 50% are finer (Reference 7). The d_{90} is defined as the diameter of sediment particles for which 90% are finer (Reference 7). To determine the size of d_{50} and d_{90}, samples of the bed material must be obtained from the study area and analyzed by sieve analysis. Standard laboratory procedures should be used when conducting laboratory sieve anlaysis. Samples must be obtained from the bed of the river, in a manner as to provide samples, which represent the actual composition of the river bed. Therefore, the following methods have been developed.

- For Shallow "WADEABLE" Streams

  Whenever possible 3 samples should be taken at locations equally spaced across the stream. If the stream has a maximum water surface width less than 40 feet, one sample on the thalweg will be sufficient. Samples should be taken at cross-sections on or near the alignment, one upstream and one downstream.

  1) Silt and Sand Bed Streams

     Samples should be collected using a 2-inch suction sampler, with the entire sample being analyzed using sieve analysis techniques.

  2) Coarse Sand to Gravel Bed Streams

     Attempt initially to use the suction sampler. If the material will not remain in the sampler, and very few fines are present, the soil auger may be used, though the finer material may be lost during extraction. If this is the case, a bucket sample should be taken from a low velocity section of the stream (if necessary away from the thalweg).

  3) Cobble to boulder bed streams

     Prior to sampling, a test hole should be dug at the water surface edge to determine if the bed surface is an armour layer. If finer material exists under the bed surface, the bucket sample method described previously should be used. If the bed sub-layers consist of similar sized material to the bed surface, the pebble count method should be adopted.

- For Deep, "NON-WADEABLE" Streams

  Sample spacing and number of samples should be the same for "wadeable" streams.

1) Silt and Sand Bed Streams

Samples should be collected using a grab type or scraping type sampler, though with both of these equipment types, some of the fines may be lost during sample retreival. If the stream is wadeable approximately halfway to the thalweg from the bank, the use of a suction sampler may be more advantageous. The sample is then analyzed using standed sieve analysis techniques. Standard?

2) Coarse Sand to Gravel Bed Streams

If the stream is wadeable to approximately halfway to the thalweg from the bank, the suction sample or soil auger should be used. The grab sampler or scraping sampler should be used on the thalweg, though if the bed is primarily coarse gravels, these samplers may be ineffective. In this case, bucket samples should be taken from the deepest water section possible. These samples should be divided and analyzed as for the "wadeable" streams.

3) Cobble to Boulder Bed Streams

Prior to sampling, a test hole should be dug at the water surface edge to determine if the bed surface is an armour layer. If finer material exists under the bed surface, the bucket sample method described previously should be used. For reasonably homogeneous sub-layer and bed material, the pebble count method, using edge of water samples should be used.

5.2 LOCAL SCOUR

5.2.1. Bridge Pier Data

Estimation of this type of local scour requires general hydraulic parameters, including the design discharge, the associated approach velocity and depth immediately upstream of the pier. The physical parameters of the pier are also required.

5.2.2 Spur Dikes and Guide Bank Data

Analysis of scour for these structures requires the same data types as required for bridge piers.

6.0 BANK MIGRATION ESTIMATION

6.1 INTRODUCTION

Bank migration (lateral stream migration) is an important consideration in design development because it may undermine bridge abutments at buried crossings. The solution is to design the pipeline emplacement to withstand the maximum lateral migration which could occur during the pipeline design flood, or bank erosion that could normally be expected during the life of the project.

In a single channel, bank erosion may result from high velocities removing bed and bank material, or from thermal erosion of channel banks. In braided rivers, it could result from a rapid change in flow pattern within, or adjacent to, an active channel area during a high discharge period. Icing (aufeis) can also cause severe bank erosion when it forms on a braided channel and blocks the existing flow, thus forming a new channel or broadening the existing channel.

Bank migration estimation, outlined in the procedure chart (Figure 3), is conducted primarily through comparative aerial photograph interpretation and on-site bank evaluations.

6.2 AERIAL PHOTOGRAPHY INTERPRETATION

Photo comparison will be used to determine historical bank migration. For each stream crossing, the distance of bank migration is measured by superposition of the earliest available photography (between 1948 and 1955) and the most recent photography. Migration at specific locations is obtained by measuring the distance of migration between photographs reduced to the same scale and preferably under similar discharge conditions. Migration rate derivation is not considered feasible as the most severe bank location changes occur during the comparatively short time periods of high flows.

The most recent aerial photography shall also be used to delineate meander patterns over long geologic time periods, and recognition of any stable geologic structures that will act as a bank migration control point. These photos shall also assist in the bank migration estimation induced by man made structures or artificially induced regime changes.

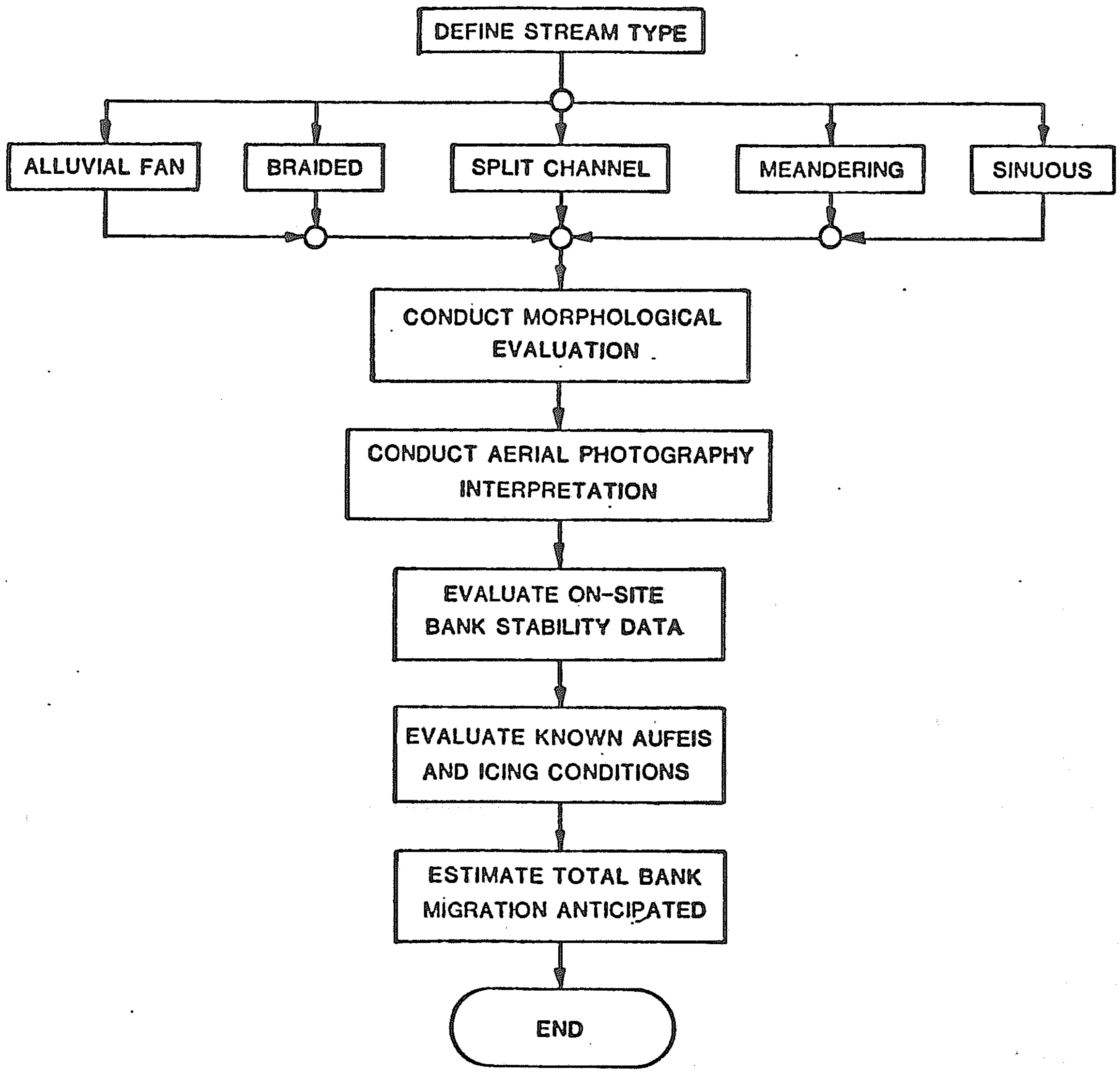

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FIGURE 3 BANK MIGRATION ESTIMATION FLOW CHART

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6.3 ON-SITE BANK EVALUATION

In conjunction with the aerial photography interpretation, the possibility of bank migration, bank incision and new channel development can be assessed through observation of the geology, vegetation, and man made structures at the site. Site-specific cross section surveys and discharge measurements will assist in delineating whether the main channel has been in its present location for many years, and whether bed material size gradation changes (heavily armoured bars or large recent sediment inflows from an adjacent tributary) may cause a shift in the main channel and potential bank scour.

Aufeis and pre-breakup field inspection data shall also be used to determine the occurrence of severe ice buildups that may induce channel shifting, extensive bank scour and consequent migration, or complete mass wasting of the banks. Past icing problems may also be revealed in the observation of swales and vegetation scars.

7.0 SCOUR DEPTH ESTIMATION AND BANK MIGRATION EXAMPLE

The following example from the Upper Tanana River stream crossing (NT 6-207, MP 666.05) summarizes the basic data input and computed data used in computing general scour and estimating bank migration.

7.1 Scour Estimation

(1)	Method used to calculate scour	Blench	
(2)	Discharge in main channel	87769	cfs
(3)	Top Width at P.D.F. Stage	21204	ft
(4)	Bankfull Width of Main Channel	697	ft
(5)	Unit Scour Discharge (q)	126	cfs/ft
(6)	Median Bed Material Size (D_{50})	.001	ft
(7)	Calculated Regime Depth (d_r)	24.6	ft
(8)	Scour Multiplication Factor (Z)	1.5	
(9)	Calculated Scour Depth (d_s)	36.9	ft
(10)	Depth of Flow at P.D.F Stage (d_w)	22.9	ft
(11)	Depth of Scour = d_s-d_w	14.0	ft
(12)	Depth of Scour plus 20%	16.8	ft
(13)	Thalweg Elevation	1595.6	ft
(14)	Streambed Elevation after Scour = (13) - (12)	1578.8	ft

(15) Bed Material Sample Location

Cross Section 489.9 (pipeline crossing) in main channel.

STREAM NAME: UPPER TANANA RIVER MP.: 688.05

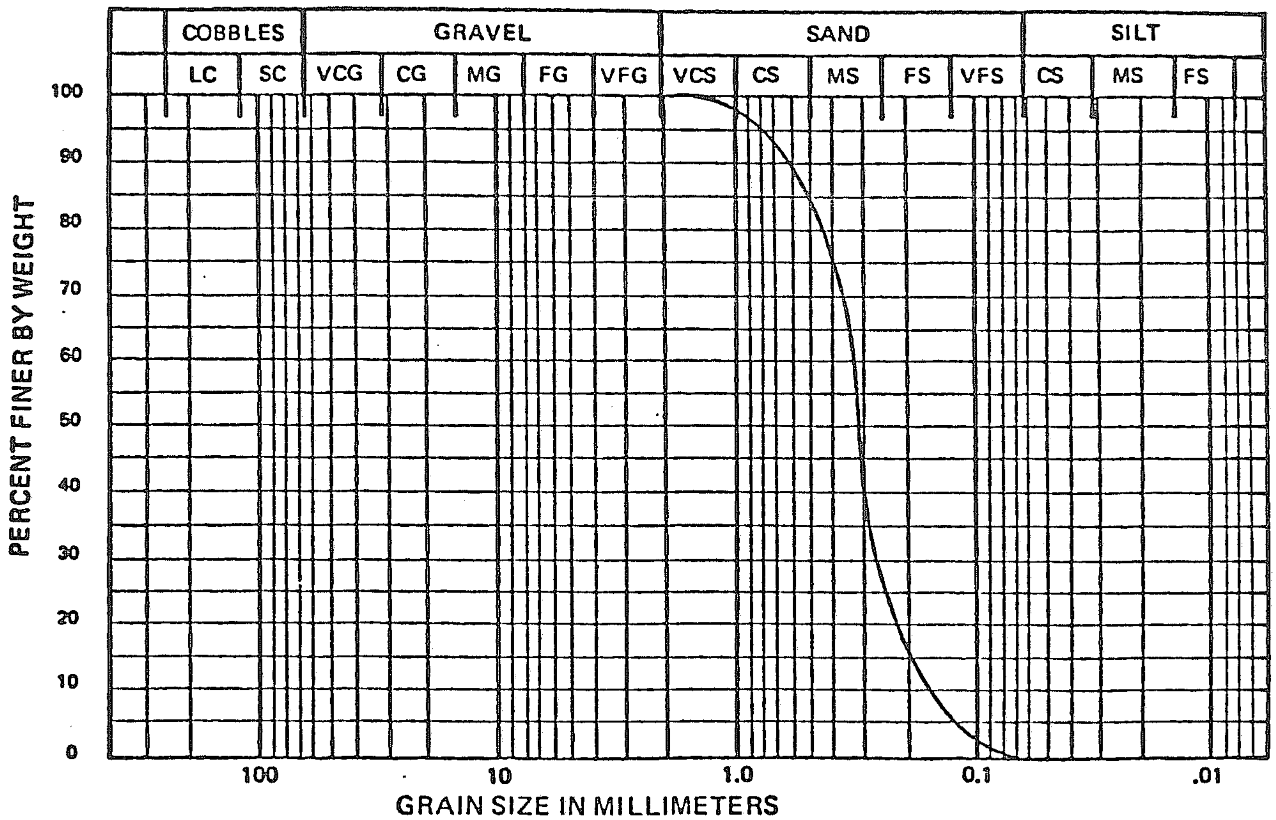
SAMPLE LOCATION: CROSS SECTION 489.9 (PIPELINE CROSSING) IN MAIN CHANNEL

DATE OF SAMPLING: JUNE 8, , 19 79 TIME:

PHOTOGRAPHS:

WEATHER:

SAMPLED BY: RECORDED BY:



d_{16}	0.20	d_{65}	0.32
d_{35}	0.29	d_{84}	0.50
d_{50}	0.31	d_{90}	0.60

$$G = 1/2\left[\frac{d_{50}}{d_{16}} + \frac{d_{84}}{d_{50}}\right] = 1.58$$

FIGURE 4

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BED MATERIAL GRADATION CURVE
UPPER TANANA RIVER CROSSING

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PWC /NWA	/					

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7.2 BANK MIGRATION ESTIMATION

Comparative aerial photograph are available for 1948 and 1978, and the superimposed locations of the tree and bank lines are shown in Figure 5.

On-site evaluation revealed that the right bank is protected by a rock outcrop at and downstream of the highway bridge. Some protection on the left bank is afforded by the highway approach, though the left overbank is low and flat, and expansion of flow downstream of the bridge is directed to the left. The channel is generally stable downstream of the Alaskan Highway, though there is potential of a meander cutoff upstream.

Very little aufeis has been observed at the site, and U.S. Geological Survey gage records for the period 1948 to 1954 make no mention of aufeis, though these records indicate large ice floes during October and November.

The measured bank migration at the pipeline crossing for the 30 year period is approximately 110 feet on the left bank and 20 feet on the right bank, with both distances indicating an enlargement of the channel. Estimated future bank migration potential is approximately 100 feet on the left bank and 20 feet on the right bank. with both migrations again indicating channel enlargement.

FIGURE 5

FLUOR PROJECT MANAGEMENT CONTRACTOR						ALASKAN NORTHWEST NATURAL GAS TRANSPORATION COMPANY
NORTEC NORTHERN TECHNICAL SERVICES						LATERAL BANK MIGRATION (PHOTO COMPARISON) UPPER TANANA RIVER CROSSING ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM
		DATE	REV.	BY	APP.	DATE
DES./DWN.	BRM/BRM					DRAWING NUMBER — REV.
CHK./APP.	/					
PMC/NWA	/					

HYDROLOGICAL SURVEYS

(1) Date of Survey(s): October, 1979

(2) Description of Adjacent Facilities:

The Alaska Highway bridge is located approximately 750 feet upstream of the pipeline crossing. The right bank is steep rock; the left bank is elevated on an gravel pad.

(3) Information on Highwater Marks, Debris, etc.:

A recent (same year) highwater mark was observed on the left pier of the bridge at an elevation of 1612.3.

(4) Overflow Channels and Potential for Meander Cutoff Development:

No flow as observed in the overflow channel. There is a strong potential for a meander cutoff along the right bank between stream mile 494.5 and 490.7.

(5) Channel/Floodpain Roughness Evaluation (Vegetation and Topography):

Stream is braided with very flat overbanks. Overbanks are vegetated with spruce and tussocks. Spruce range from 6-inch diameter near the channel to 2-inch diameter on the overbank.

(6) Channel Bed Material Description and Potential for Armor Layer Development:

Bed material is medium sand. No armor layer was observed.

8.0 REFERENCES

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